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(E82-10304) [INVESTIGATING TECTONIC AND BATHYMETRIC FEATURES OF THE INDIAN OCEAN USING MAGSAT MAGNETIC ANOMALY DATA] Quarterly Progress Report, 1 Sep. - 31 Dec. 1981 (Analytic Sciences Corp.) 17 p HC A02/MF A01 G3/43 N82-24578 Unclas 00304

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Goddard Space Flight Center
Greenbelt, Maryland

Prepared by:

Andrew R. Lazarewicz
Richard V. Sailor

Approved by:

Robert F. Brammer

THE ANALYTIC SCIENCES CORPORATION
One Jacob Way
Reading, Massachusetts 01867-3992

1. INTRODUCTION

The TASC Magsat investigation covers an area in the eastern Indian Ocean which contains several major bathymetric and tectonic features (Fig. 1-1). The overall objectives of this investigation are:

- Determination of the optimum resolution of Magsat anomaly maps of the study region.
- Production of magnetic anomaly maps from Magsat data covering the study region (0 - 50 degrees S, 75 - 125 degrees E).
- Comparison of Magsat and satellite altimeter (geoid undulation) data in this area, and quantification of their relationships.
- Interpretation of the Magsat data using satellite altimeter and other geophysical data in order to determine the origin and sources of the observed magnetic anomalies.

The investigation area consists of a variety of geologic features including two ridges, a trench, fracture zone and plateau. Figure 1-2 is the contoured bathymetry with a 1-degree resolution (Rapp, 1981), showing the locations of the major bathymetric features.

The investigation during this quarter focused in three areas:

- PREPROCESSING MAGSAT DATA

  The Magsat Investigator-B tapes were preprocessed by 1) removing all data points with obvious erroneous values and location errors, 2) removing smaller spikes (typically 15 nT or more), and deleting data tracks with fewer than 20 points, and 3) removing a linear trend from each track. The remaining data was recorded on tape for use by the ESMAP program.

- IMPLEMENTING ESMAP

  The NASA-supplied program, ESMAP (Equivalent Source MAPping), uses a least-squares algorithm to fit the magnetization parameter of a grid of equivalent source dipoles in the crust to satellite data acquired at different locations and times. ESMAP was implemented on the TASC computing system and modified to 1) read preprocessed Magsat data tapes and 2) interface with TASC plotting software. Some verification of the software was accomplished by testing against model anomaly fields.

- ACCESS TO GRIDDED GRAVITY DATA

  Gridded 1-degree mean values of gravity anomaly and sea-surface undulation computed from the Seasat radar altimeter were obtained and brought on line for use in the upcoming quarter.

Interpreting magnetic and gravity anomaly maps usually begins with spatial correlation of anomaly features with geologic features. Inferring more detailed geophysical information from magnetic data requires estimation of the magnetic susceptibility for regions of the crust from the computed magnetization values for the equivalent source dipoles. Gravity anomaly and sea-surface undulation (approximation to the geoid) data are used to estimate or limit density structure.

Gridded gravity anomaly data at sealevel can be upward continued and compared with gridded, reduced to the pole, magnetic anomaly data at the same altitude. Using the combined magnetic and gravity data, estimates of the contrasts in density, susceptibility, and perhaps rock type may be made. The progress for this quarter focused on the acquisition or generation of gridded anomaly maps.

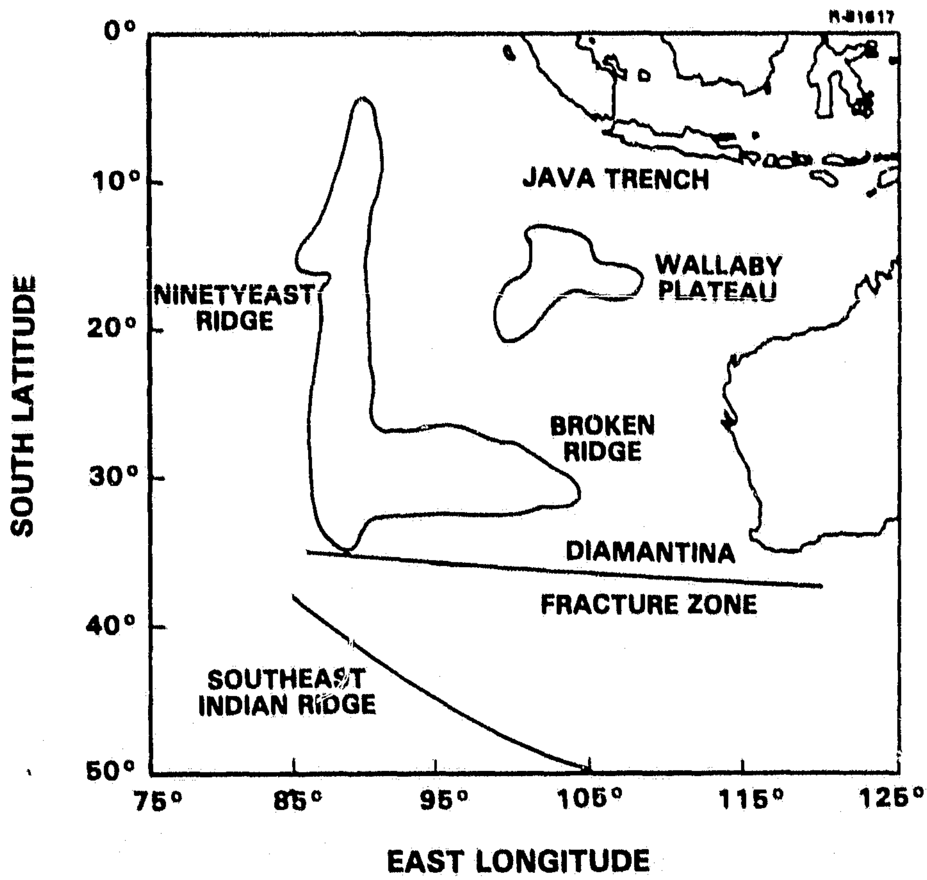

Figure 1-1 Investigation area showing major tectonic features

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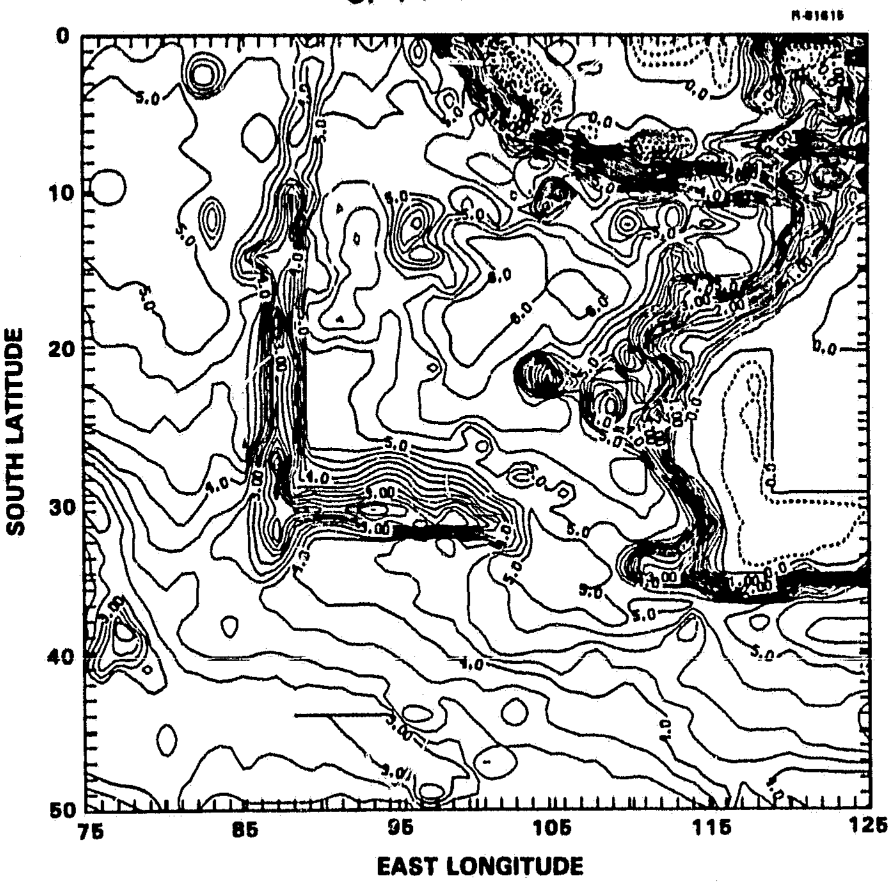

Figure 1-2 Investigation area showing bathymetry at a one degree resolution. The area without data in the middle of the right-hand side of the plot is over Australia.

2. TWO DIMENSIONAL MAPPING OF THE MAGNETIC ANOMALY FIELD

2.1 METHOD

The NASA-supplied Investigator-B tapes ("quiet time" Magsat data for the TASC investigation area) were previously found to contain bad data points which were categorized as follows (Ref. 1): 1) known missing data values (flagged with a 99999.0) and 2) isolated data spikes with values greater than about 15 nT. There are also points with incorrect values for latitude, longitude, or altitude. These points and all tracks consisting of less than 20 points were deleted from the investigation data set. A linear trend was removed from each track of data to reduce the effects of external fields. Since we believe that the data sampling rate can be lowered (Ref. 1), the remaining edited and de-trended data was averaged over five consecutive points and stored on a new and condensed version of the Investigator-B tapes. This averaging increased the sampling interval from 36 to 180 km.

The goals of this research include producing a magnetic anomaly map and forming a joint interpretation of magnetic and gravity anomaly data. To accomplish these tasks, it is necessary to reduce the Magsat data to a regular grid at a constant altitude and to infer the associated crustal magnetization. The computer program ESMAP, obtained from NASA, is particularly well suited for these purposes. ESMAP uses a least-squares fitting algorithm to adjust a magnetization parameter (dipole moment per unit volume) of individual tracks arranged in a grid of dipoles such that the resulting field fits the input satellite scalar data. The dipoles are located

in the crust and oriented along the Earth's main magnetic field to simulate induced magnetization. Once the magnetization parameters have been determined for the equivalent source dipoles, a gridded magnetic anomaly map can be computed from those dipoles. The resulting anomaly map can be reduced to the pole by reorienting the dipoles to a vertical position. During this Quarter, ESMAP was modified to work on the TASC computing system, tested, and interfaced with TASC's contour plotting package whose results are in the figures in this report.

Since ESMAP is a complex software package, several tests were run to check for internal consistency, and an attempt at independent verification of the computed field points was made. The purpose of the testing was to 1) check that ESMAP could reproduce a model anomaly field (internal consistency), and 2) convert the magnetization parameter computed for the model dipoles into an estimate for magnetic susceptibility. Given the magnetization parameter of a single dipole, a computation independent of ESMAP for the resulting field can be made and compared with ESMAP computations.

Three tests were run, leading to a preliminary equivalent dipole source model and estimated anomaly map for the TASC investigation area. Test 1 fit a matrix of 25 dipoles in the investigation area to a small number of data tracks and computed an anomaly field. Test 2 fit a single, centered dipole to the resulting field from Test 1 and computed an anomaly field and a reduced-to-pole anomaly field. Finally, Test 3 fit a matrix of 25 dipoles to the anomaly field from Test 2. These tests confirmed the internal consistency of the ESMAP algorithm. Each test (Sections 2.2 - 2.4) and the preliminary model of the field (Section 2.5) covered the entire 50 by 50 degree area and produced anomaly maps on a 1 by 1 degree scale

at 350 km altitude. All of these magnetic anomaly maps have inaccuracies near the edges (a 12.5 degree border) as described by Horner (Ref. 2).

2.2 TEST 1: INITIAL SOFTWARE TEST

Thirty tracks (3621 points) of data were processed to fit 25 dipoles (10 degree spacing). The results are shown in Fig. 2-1a. The first estimate for the anomaly field compares satisfactorily with the published two degree Magsat map (Ref. 3) regarding the location and amplitude of the major feature located near the Broken Ridge. However, the broad spacing of the dipole locations leads to a "ripple" effect visible in the anomaly map and clearly indicates the need for a denser dipole grid in the further stages of this investigation.

2.3 TEST 2: SINGLE DIPOLE FIT AND REDUCTION TO POLE

The gridded anomaly map resulting from Test 1 was used as input data for this test. A single, centered dipole was fit to the 2601 input data points. The purpose of this test was to generate a single dipole field. It was simpler to let ESMAP fit a single dipole field to an arbitrary field, than to generate a single dipole field analytically. Since only one dipole was fit, the magnetization has a very high value which is not geophysically significant. However this particular dipole will be used to test the internal consistency of ESMAP. After solving for the dipole parameters, the dipole was rotated to a vertical position, and its field computed (Fig. 2-1b). The resulting field shows that the reduction to the pole worked correctly. The computed magnetization parameter and the field are in a form which can be, but has

not yet been, verified in a straightforward manner using standard far field formulas for a simple dipole. This verification requires conversion of the magnetization parameter to a dipole moment in the appropriate units, and will have geophysical significance when related to the magnetic susceptibility of the local rock.

Figure 2-1c shows the resulting field when the dipole is not reduced to the pole. The resulting fields are consistent with those expected from a single dipole field. The shape distortion from the input field is due to the use of a single dipole, and the large field magnitude is due to the attempt to fit the magnetization parameter of a single dipole to relatively large values (10 nT) of the field far from the dipole. This is an extreme case of using an insufficient number of dipoles to fit the input field data, as can be seen in the unrealistic value for the magnetization parameter, and an obviously poor fit to the input magnetic field model.

2.4 TEST 3: LEAKAGE AMONG MODELED DIPOLES

A final consistency test was performed by using the computed field shown in Fig. 2-1c as the input data, and solving for a matrix of 25 dipoles, the center one being located at the same location as the single dipole of Test 2. The dipoles in this case have a 10 degree spacing. The resulting field is shown in Fig. 2-1d, and is visually indistinguishable from Fig. 2-1c. The value of the magnetization parameter of the centered dipole is 25 times the value of the single dipole (as the volume is 25 times smaller), and the surrounding 24 dipoles have magnetization parameter values more than 5 orders of magnitude smaller than the value for the central dipole.

Thus ESMAP is a self-consistent program to generate gridded anomaly fields and does not significantly "leak" magnetization from dipole to dipole.

2.5 PRELIMINARY ANOMALY MAP OF THE INVESTIGATION AREA

A first computation of the anomaly field for the entire investigation area was made using the maximum number of dipoles (software limited) which could be fit in the area with a single computer run. Final mapping will subdivide the investigation area to decrease the dipole spacing, thus requiring multiple computer runs. For the preliminary map, 144 dipoles with a spacing of 4.67 degrees were used. A significant portion of the TASC Magsat Investigator-B quiet time data (50,104 points in 379 data tracks) was used as the input data. The field estimate was computed (Fig. 2-2), and due to the large spacing among the modeled dipoles, the "ripple" effect is still evident. The overall fit of field magnitude and feature location corresponds well, by visual inspection, with the published Magsat two-degree anomaly map (Ref. 3). The latter was mapped using averages at satellite altitude of data within 2 by 2 degree squares, and did not use equivalent dipole source modeling.

The strongest features evident in the computed anomaly map are located near the Broken Ridge, the west cost of Australia, and the Diamantina Fracture Zone (Figs. 2-1, 2-2). Surprisingly, there is no major anomaly feature visible at the Ninetyeast Ridge, which is adjacent to the Broken Ridge. As previously mentioned, the computed anomaly values in the 12.5 degree border are degraded due to edge effects of the ESMAP modeling algorithm. Subsequent maps will be designed to be overlapped so that the inaccurate anomaly values in the borders are not used.

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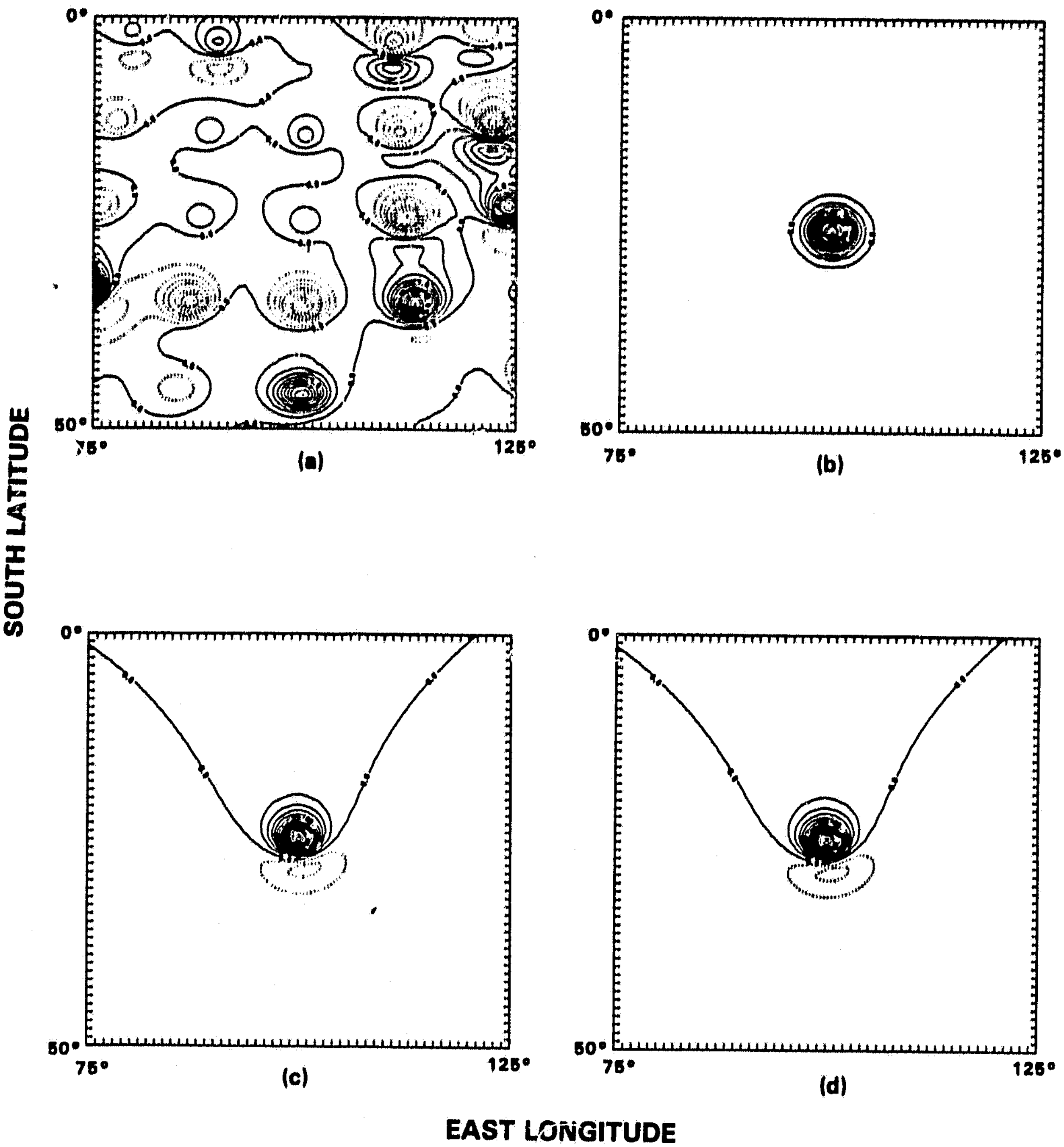

Figure 2-1 a) A 25 dipole fit to 3621 points; b) a 1 dipole fit to the result computed in (a), the output field is reduced to the pole; c) same as (b) but not reduced to the pole; d) a 25 dipole fit to the result computed in (c). Contours are in nT with 0.25 nT spacing

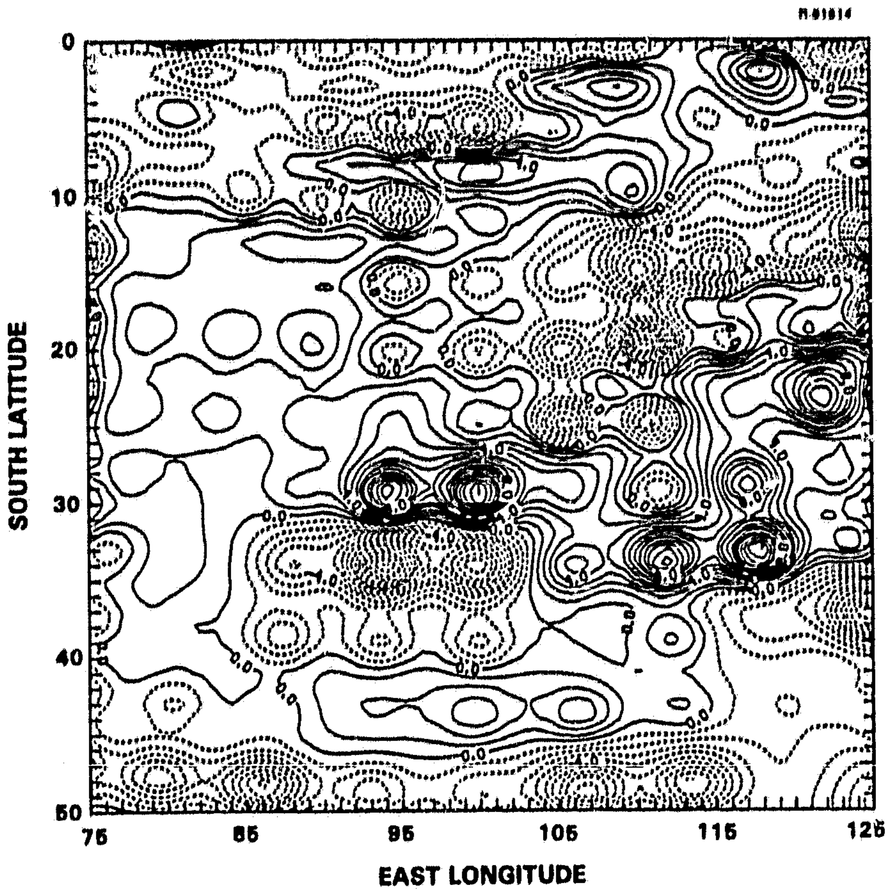

Figure 2-2 Preliminary Magsat anomaly map with 144 dipoles fit to 50104 data points. Contours are in nT with a 0.25 nT spacing

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3. TWO DIMENSIONAL MAPPING OF GRAVITY DATA

Gridded data of sea-surface undulation and gravity anomaly values were obtained from Professor Richard Rapp of the Ohio State University (Ref. 4). These data represent mean values in one by one degree squares and were computed from Seasat radar altimeter data. Figure 3-1 shows the sea-surface undulation map and Fig. 3-2 shows the gravity anomaly map, presented at the same scale as Figs. 1-1 and 1-2. The major features in the gravity anomaly map are associated with the Ninetyeast Ridge and Java Trench. The Broken Ridge, correlated with a strong magnetic anomaly feature, does not have a pronounced correlated feature in the gravity anomaly map. For proper comparison with magnetic data, the gravity anomaly map must be upward continued to the altitude (350 km) of the magnetic data. This operation will be performed during the next quarter.

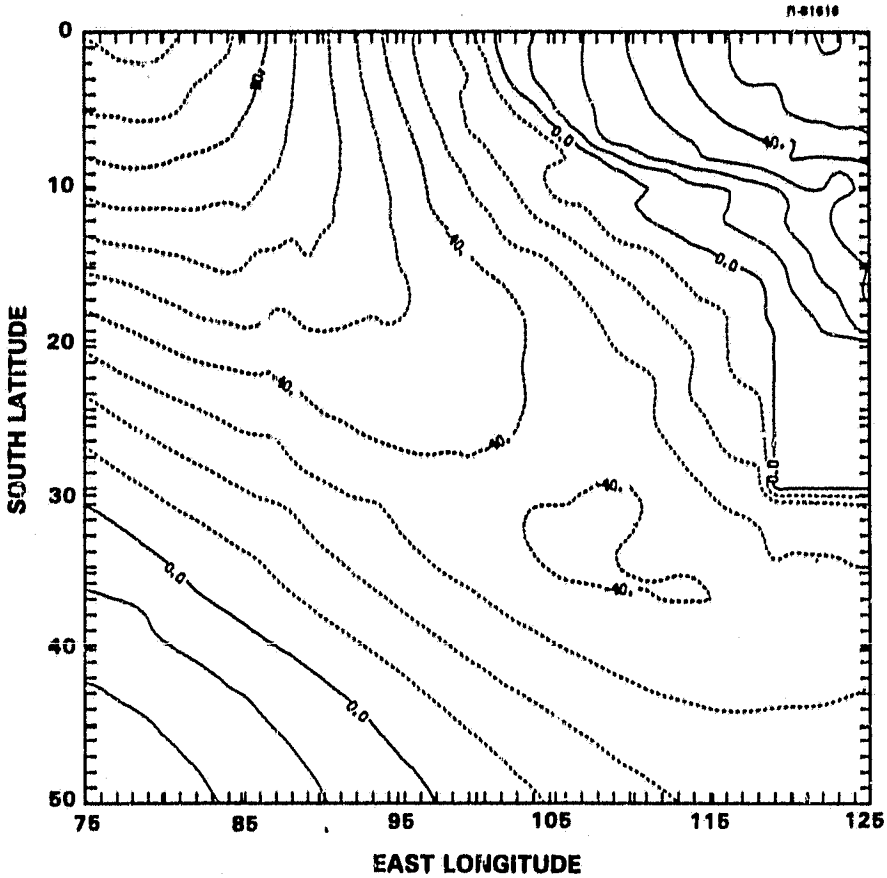

Figure 3-1 Seasat derived sea-surface undulation map. Contours are in meters with 10 meter intervals

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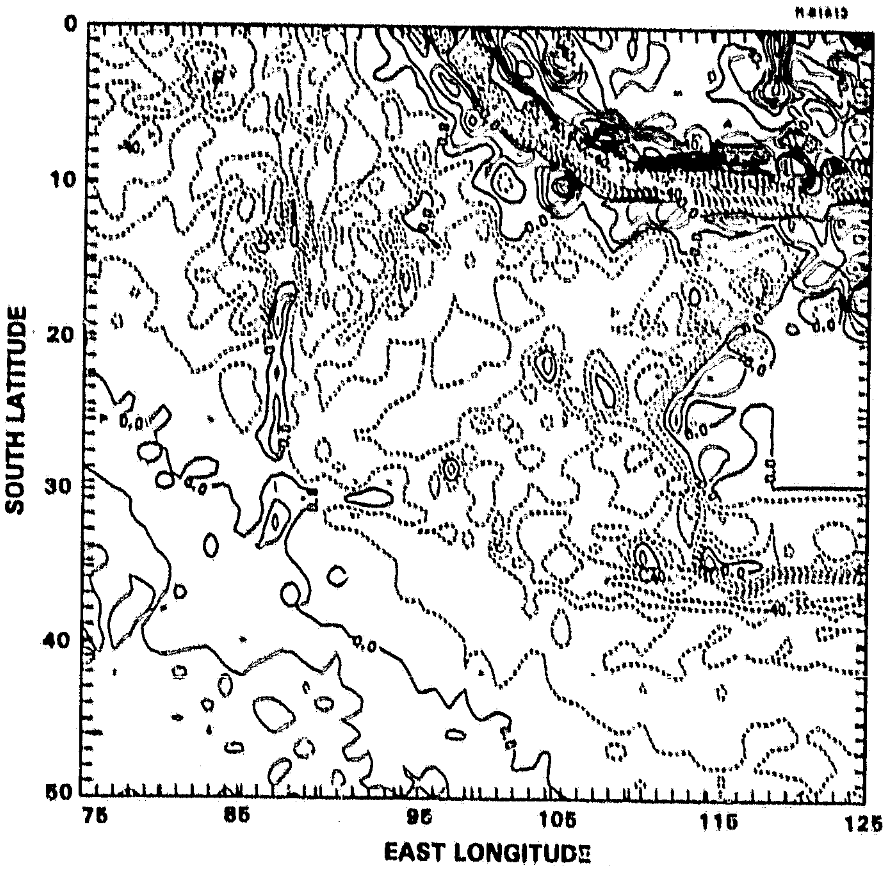

Figure 3-2 Seasat derived gravity anomaly map. Contours are in mgals, with 10 mgal intervals

4. UNRESOLVED PROBLEMS AND FUTURE DIRECTIONS

ESMAP was designed for gridding satellite data by computing parameter values of the equivalent source dipoles. The major issue not solved during this quarter was a determination of the relationship of the computed model magnetization parameter for the dipoles (as output by ESMAP) with the magnetic susceptibility of the rock.

The resolution limit of the magnetic anomaly data was previously estimated at 250 km (Ref. 1). Work will continue toward the determination of the optimum dipole spacing for equivalent source modeling, which is not equivalent to the resolution limit of the anomaly maps. This information will be used to produce a reduced-to-pole magnetic anomaly map of the investigation area. The gravity anomaly data will be upward continued to the altitude of the magnetic anomaly data, allowing comparisons of the two data sets. The first major geophysical implications of these analyses will be from classification of the major tectonic features in the investigation area.

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2. Horner, R.J., Jr., "The Equivalent Source Magnetic Anomaly Program (ESMAP) User's Guide," Prepared by Computer Sciences Corporation for Goddard Space Flight Center, 1980.

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4. Rapp, R.H., "1-Degree Mean Gravity Anomaly and Sea-Surface Undulation Data Base," Personal communication, 1981.